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Identification of mobile minirobot

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The article demonstrate mode of utilization of fuzzy logic to simulation of identification systems. Real data, received from real object - mobile minirobot, has been used to simulations and analysis. Numerical calculations have been done in the Matlab^{TM}-Simulink programmer environment.

Keywords: Dynamics, identification, simulations

1. Introduction

The concerning steering mobile wheel robots are complex due to the fact that these object are nonlinear, nonholomic and multidimensional systems. The correct analysis of these problems, especially the dynamics of dynamic systems, requires identifying dynamic equations of motion. Therefore, to analyze the problems of 2-wheels minirobot identification the methods of artificial intelligence these were used; do not require linear forms on account of the model parameters. The detailed description of $M.R.K$ construction and (the accepted model) was presented in the article *Mechatronics of mobile minirobot* $M.R.K$ placed in this publication.

2. Dynamic equations of the mobile minirobot M.R.K.

Dynamic equations of mobile minirobot MRM [1,2,3,4,5]:

$$M(a)\ddot{q}_2 + C(a,\dot{q}_2)\dot{q}_2 + F(a,\dot{q}_2) = D(a)M_n \tag{1}$$

where matrixes and vectors have the following form:
q_1 – vector of generalises displaces, M – matrix of inertia, C – matrix of centrifugal and Corioli's forces, F – vector of motion resistance, D – matrix of amplification

$$q_2 = \begin{bmatrix} \beta & \alpha \end{bmatrix}^T, \quad M(a) = \begin{bmatrix} a_1 & -a_2 \\ -a_2 & a_3 \end{bmatrix},$$
$$C(a, \dot{q}_2) = \begin{bmatrix} 0 & -a_4\dot{\beta} \\ a_4\dot{\beta} & 0 \end{bmatrix}, \tag{2}$$
$$F(a, \dot{q}_2) = \begin{bmatrix} (a_5 - a_7) \cdot a_6 & a_5 + a_6 \end{bmatrix}^T,$$
$$D(a) = \begin{bmatrix} a_7 & -a_7 \\ 1 & 1 \end{bmatrix}, \quad M_n = \begin{bmatrix} M_1 & M_2 \end{bmatrix}^T.$$

3. Identification of $M.R.K$ motion parameters

The problems of dynamic objects modelling and identification [2,10,12] are basic in the methods of control system design. The acquaintance with detailed mathematical description of the object or building its simulator enables to develop control systems which are more efficient comparing to systems developed without such knowledge. The theory of identification refers especially to linear static and dynamic object, and nonlinear problems taking into consideration their diversity and complexity – are solved through various proximate method and techniques. The correct analysis of dynamics of dynamic system requires identifying dynamic motion equation. Identification problem is understood as choosing the best model in the class of models formulated on the basis of mathematical description for physical phenomena which proceed in a real object.

In this point fuzzy logic were used to solve the identification problem. The problem was discussed for a mobile wheel robot in serial-parallel structure with Gauss affiliations functions. The dynamic equations of the mobile robot motion were:

$$\dot{x} = Ax + B\left[f(x) + G(x)u\right] \tag{3}$$

It assumed that state variables $x = \left[\dot{\beta},\, \dot{\alpha}\right]^T$ and driving moments $u = [M_1,\, M_2]^T$ are known.

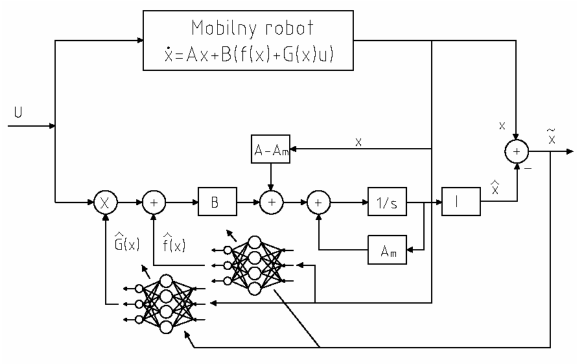

Figure 1 General scheme of parallel-serial-parallel identification system

3.1. *Am project matrix*

The above system will be stable when a suitable stable A_m project matrix [10,12] is matched. For this reason, A_m expression is added to and subtracted from equation (3), with the following result:

$$\dot{x} = A_m x + (A - A_m)x + B\Big[f(x) + G(x)u\Big] \tag{4}$$

Equations (4) defines series-parallel structure of the identifier.

$$\dot{\hat{x}} = A_m \hat{x} + (A - A_m)x + B\Big[\hat{f}(x) + \hat{G}(x)u\Big] \tag{5}$$

Where vector $\hat{x}$ is an estimator of state vector and $\hat{f}(x)$, $\hat{G}(x)$ are estimates of nonlinear functions in the equations (4).

State estimation error was defined as:

$$\tilde{x} = x - \hat{x} \tag{6}$$

Subtracting equation (4) from equation (5) the following description of identification problem in error space was received:

$$\dot{\tilde{x}} = A_m \tilde{x} + B\Big[\tilde{f}(x) + \tilde{G}(x)u\Big]$$

Where

$$\tilde{f}(x) = f(x) - \hat{f}(x) \qquad \tilde{G}(x) = G(x) - \hat{G}(x) \tag{7}$$

3.2. *Fuzzy logic applied in identification process*

For the approximation of nonlinear function present in equation (3) it is possible to apply fuzzy logic of Takagi Sugeno [9,11] type, with the structure as shown below The analysed TAKAGI-SUGENO fuzzy model is charakterized by rule baze where

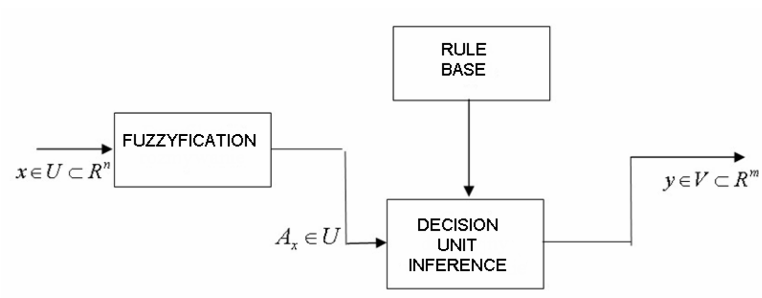

Figure 2 Fuzzy model scheme

IF part is fuzzy while in THIS part functional dependence is present:

Rj: IF x_1 is A_1^j *I* x_2 be $A_2^j \ldots$ I x_n be A_n^i THIS $y_j = g_j(x_1, x_2, \ldots, x_n)$

Accepting on input of block the inference fuzzy set Ax with minimum or maximum t-norm

$$\mu_{A_1^j x \ldots x A_n^j}(x) = \max\left[\mu_{A_1^j}, \ldots, \mu_{A_n^j}\right] \tag{8}$$

On output was received a signal equal to standard sum

$$y(x) = \frac{\sum_{j=1}^{M} \bar{y}_j \tau_j}{\sum_{j=1}^{M} \tau_j} \tag{9}$$

Where

$$\tau_j = \prod_{i=1}^{n} \mu_{A_i^j}(x_i) \tag{10}$$

Fuzzy block transforms input space $X = [\dot{\alpha}_1, \dot{\alpha}_2] \subset R^n$ into fuzzy set $A \in X$ characterized by affiliation function $\mu_A(x) : X \to [0, 1]$, which means it determines fuzzy sets.

A fuzzy logic system made in MATLAB/SIMULINK program was used for the control system; it enables creation of fuzzy models with the use of additional options set (fuzzy logic toolbox) [13]. This tool facilitates the designing process and the selection of system parameters.

4. Numerical verification

The simulation objective was modelling of fuzzy logic system for serial-parallel identifier. This system was based on fuzzy logic with GAUSS affiliation function [2,6,10,12]. Applying this method (the course of) calculation will be simplified, comparing to complicated and time-consuming. All coefficients required for realization of identification process were selected through many simulations and numerical experiments.

The criterion used in their selection was minimizing of error value identification signal $\dot{\alpha}$ and $\dot{\beta}$.

The results of the simulations carried out in MATLAB/SIMULINK program [7,13] are shown below. They prove that the selected criteria had a considerable influence on the task completion time as well as the formed identification errors.

The choice of A_m design matrix had a significant impact on the obtained results; at the same time exceeding its maximal value i.e. $A_m = 100$ caused the instability of the whole system. The identification time was extended and the oscillation of output signal appeared. The obtained results proved the usefulness of the identification process; above all the chosen model was correctly selected with for simulated design of $M.R.K$ minirobot.

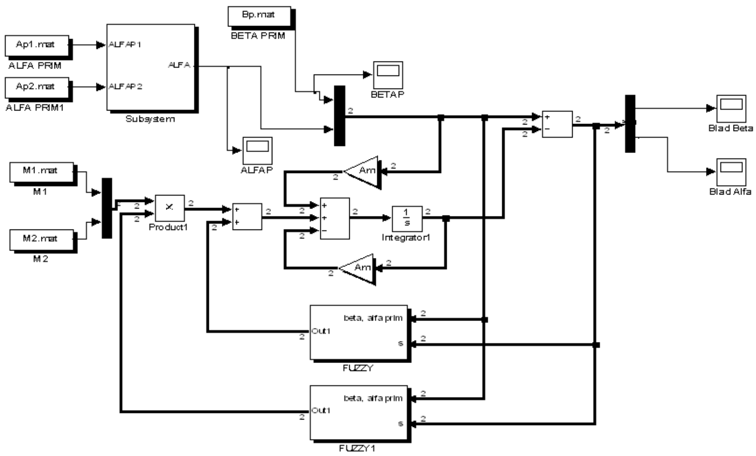

Figure 3 Fuzzy identification system

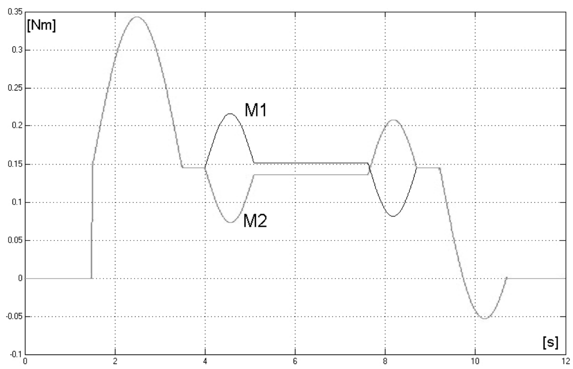

Figure 4 Input function signals

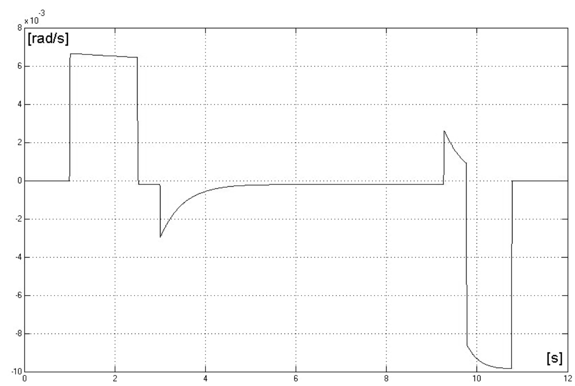

Figure 5 Identification error of velocity α

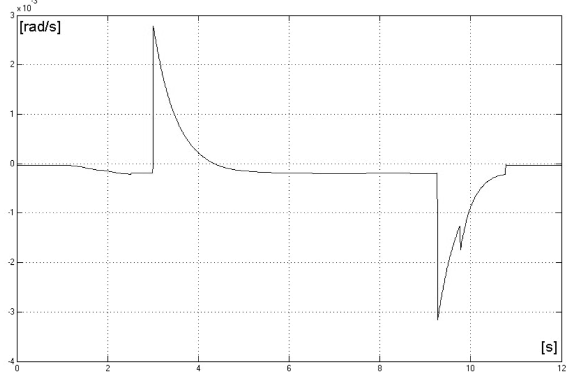

Figure 6 Identification error of velocity β

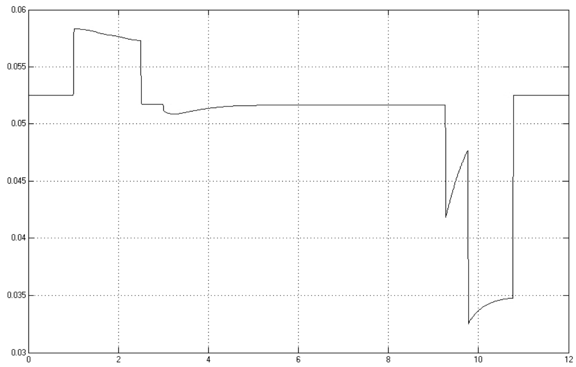

Figure 7 Signal from fuzzy block for $\dot{\alpha}$

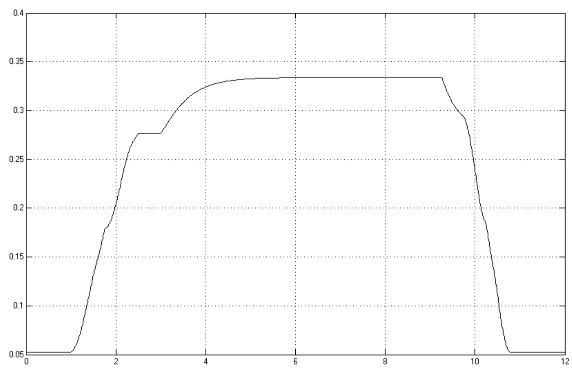

Figure 8 Signal from fuzzy block for $\dot{\beta}$

5. Summary

In this publication the authors created original computational models of identification structures in Matlab/Simulink programme, basing on mathematical descriptions accessible in the literature of the subject.

Off-line identification procedures were presented and fuzzy systems were modelled with the use of fuzzy logic toolbox. The application of fuzzy logic in steering mobile robots considerably eliminates problems of with nonlinearity occurring in this type of systems, with significantly simplifies their further verification. The analysis and simulations carried out proved the selection of the limits when the model becomes unstable.

The description of $M.R.K$ design and detailed research into kinematics and dynamics were presented in the article *Mechatronics of wheel minirobot* $M.R.K$, a part of this publication.

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